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(54) Metals recovery by flotation

(57) Froth flotation processes for the beneficiation of platinum, gold and/or silver values from base metal sulfide ores employ a dithiophosphinate as the collector. The use of the dithiophosphinate provides excellent metallurgical recoveries of platinum, gold and silver values in froth flotation processes conducted over a broad range of pH conditions including acid, neutral alkaline pH.

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IMPROVED METAL RECOVERY BY FLOTATION

BACKGROUND OF THE INVENTION

The present invention relates to froth flotation processes for recovery of gold, silver and/or platinum group metal values from base metal sulfide ores. More particularly, it relates to improved sulfide collectors comprising certain dithiophosphinates which exhibit excellent metallurgical performance over a broad range of pH values.

Froth flotation is one of the most widely used processes for beneficiating ores containing valuable minerals and is described in U.S. Patent No. 4,584,097, hereby incorporated herein by reference.

The success of a sulfide flotation process depends to a great degree on the reagent(s) called collector(s) that impart(s) selective hydrophobicity to the value sulfide mineral that has to be separated from other minerals. Thus, the flotation separation of one mineral species from another depends upon the relative wettability of mineral surfaces by water. Typically, the surface free energy is purportedly lowered by the adsorption of heteropolar collectors. The hydrophobic coating thus provided acts in this explanation as a bridge so that the mineral particles may be attached to an air bubble. The practice of this invention is not, however, limited by this or other theories of flotation.

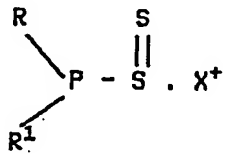
Xanthates, dithiophosphates, alkyl xanthogen alkyl formates, bis alkyl xanthogen formates,

dialkylthionocarbamates, hydrocarboxycarbonyl thionocarbamates, etc. have been shown to be useful collectors in froth flotation procedures. Most of these known collectors, however, are known to suffer from at least one deficiency which prevents them from being used universally for the recovery of metals from each and every ore requiring refining, such as pH dependency, affinity for some metals versus others etc.

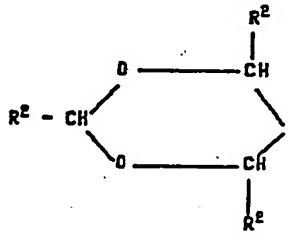
The use of dithiophosphinates collectors for the recovery of copper is well known, see U.S. Patent No. 3,355,017. The recovery of gold from gold containing tailings or primary gold ores with dicresyl monothiophosphate is disclosed in 1) Nagaraj et al; XVI International Minerals Processing Congress, Stockholm, Sweden, June 5-10, 1988; Edited by E. Forssberg; Elsevier Science Publishers B.V. Amsterdam; 2) Nagaraj et al; Proceedings of the II International Mineral Processing Symposium; Ixmir, Turkey; Oct. 4-6, 1988; Dokuz Eylul University; Dept. of Mining Eng.; Bornova; 3) Nagaraj et al, Development of New Sulfide and Precious Metals Collectors, Presentation at the CIM; Sept. 1987, New Brunswick, N.J. Additionally, U.S. Patent Nos. 2,919,025 and 3,317,040 disclose the recovery the copper from copper ores utilizing monothiophosphites under alkaline conditions. None of these publications, however, disclose the recovery of gold, silver and/or platinum, etc. with dithiophosphinates from other metals at acid or alkaline pH. It is therefore unexpected that dithiophosphinates, in precious metal flotation, have been found to exhibit such a high selectivity for gold, silver and platinum group metals.

SUMMARY OF THE INVENTION

In accordance with the present invention, there is provided a new and improved process for beneficiating an ore containing sulfide minerals with selective rejection of oxides and carbonates, said process comprising: grinding said ore to provide particles of flotation size, slurrying said particles in an aqueous medium, conditioning said slurry with effective amounts of a frothing agent and a metal collector, and frothing the desired sulfide minerals preferentially over gangue minerals by froth flotation procedures; said metal collector comprising at least one dithiophosphinate compound having the formula:



wherein R and R^1 are, individually, C_5-C_{12} alkyl radicals or R and R^1, together, form a cycloalkyl C_4 - C_{10} or a



radical, wherein R^2 is a C_1-C_8 alkyl radical and X is a cation.

In particularly preferred embodiments, a new and improved method for enhancing the recovery of gold, silver and platinum group minerals from an ore containing a variety of sulfide minerals is provided.

The present invention therefore provides a new and improved process for froth flotation of base metal sulfide ores. The dithiophosphinates collector and the process of

the present invention unexpectedly provide superior metallurgical recovery in froth flotation separations as compared with many conventional sulfide collectors, even at reduced collector dosages, and are effective under conditions of acid, neutral or mildly alkaline pH. In accordance with the present invention, a sulfide ore froth flotation process is provided which provides for superior beneficiation of gold, silver and platinum group mineral values.

Other objects and advantages of the present invention will become apparent from the following detailed description and illustrative working examples.

DETAILED DESCRIPTION OF THE INVENTION

In accordance with the present invention, gold, silver and platinum group metal values are recovered by froth flotation methods in the presence of a novel sulfide collector, said collector comprising a dithiophosphinate of the formula, above.

In accordance with the present invention, the above-described dithiophosphinate collectors are employed in a new and improved froth flotation process which provides a method for enhanced beneficiation of gold, silver and platinum group metal values from base metal sulfide ores over a wide range of pH and more particularly under acidic, neutral, slightly alkaline and highly alkaline conditions.

In accordance with the present invention, the new and improved, essentially pH-independent process for the beneficiation of gold, silver and platinum group metal values from base metal sulfide ores comprises, firstly, the step of size-reducing the ore to provide ore particles of flotation size. Generally, and without limitation,

suitable particle size will vary from between about 5 microns to about 300 microns. Preferably, the ore will be size-reduced to provide flotation sized particles of between about 30 microns and about 200 microns. Especially preferably for use in the present method are base metal sulfide ores which have been size-reduced to provide from about 14% to about 30%, by weight, of particles of 75 microns and from about 45% to about 75%, by weight of particles of 38 microns.

Size reduction of the ores may be performed in accordance with any method known to those skilled in this art.

Preadjustment of pH is conveniently performed by addition of the modifier to the grind during the size reduction step.

The pH of the pulp slurry may be pre-adjusted to any desired value by the addition of either acid or base, and, typically, sulfuric acid or lime are used for this purpose, respectively. Thus, for example, good beneficiation has been obtained in accordance with the process of the present invention at pH values ranging between 3.5 and 11.0, and especially good beneficiation has been observed with pH values within the range of from about 4.0 to about 10.0 pH.

The size-reduced ore, e.g., comprising particles of liberation size, is thereafter slurried in aqueous medium to provide a floatable pulp. The aqueous slurry or pulp of flotation sized ore particles, typically in a flotation apparatus, is adjusted to provide a pulp slurry which contains from about 10 to 60%, by weight, of pulp solids, preferably, 25 to 50%, by weight, and especially

preferably from about 30% to about 40%, by weight, of pulp solids.

In accordance with a preferred embodiment of the process of the present invention, the flotation of gold, silver and platinum is performed at a pH of over 7.0 whereas the value flotation is performed at a pH of less than or equal to 6.0 and preferably less than 4.0. It has been discovered that in conducting the flotation at this pH, the collectors of the present invention exhibit exceptionally good collector strength, together with excellent collector selectivity, even at reduced collector dosages. It is to be understood however, that gold and silver ofttimes may be recovered at basic pH and platinum may be recovered at acidic pH.

After the pulp slurry has been prepared, the slurry is conditioned by adding effective amounts of a frothing agent and a collector. By "effective amount" is meant any amount of the respective components which provides a desired level of beneficiation of the desired metal values. Generally, about 0.005 to about 0.5 lb. of collector per ton of ore is sufficient.

Any known frothing agent may be employed in the process of the present invention. By way of illustration, such frothing agents as straight or branched chain low molecular weight hydrocarbon alcohols, such as C_6 to C_8 alkanols, 2-ethyl hexanol and 4-methyl-2-pentanol, also known as methyl isobutyl carbinol (MIBC) may be employed, as well as pine oils, cresylic acid, polyglycol or monoethers of polyglycols and alcohol ethoxylates, to name but a few of the frothing agents which may be used as frothing agent(s) herein. Generally, and without limitation, the frothing agent(s) will be added in

conventional amounts and amounts of from about 0.01 to about 0.2 pounds of frothing agent per ton or ore treated are suitable.

Thereafter, the conditioned slurry, containing an effective amount of frothing agent and an effective amount of collector, is subjected to a frothing step in accordance with conventional froth flotation methods to float the desired sulfide mineral values in the froth concentrate and selectively reject or depress other gangue minerals.

The improved collectors of the present invention may be added to the flotation cell as well as to the grind.

The collectors of the present invention have been described for use in those applications wherein it is desired to selectively concentrate or collect certain platinum, gold and silver from gangue materials, e.g., silicates, carbonates, oxides, etc.

The collectors of the present invention may be used alone, however, it is ofttimes preferred to use them in conjunction with such auxilliary collectors as dithiophosphates, dithionocarbamates, xanthates, mercaptobenzothiazoles, and the like, in amounts ranging from about 5-95% to about 95-5%, respectively.

The R and R^1 radicals of the dithiophosphinates compounds of the above formula may, independently, be selected from pentyl, n-hexyl, cyclohexyl, heptyl, octyl, 2,4,4-trimethylpentyl, decyl, dodecyl etc. When R and R^1, together, form substituents on the phosphorous atom of the above dithiophosphinates, such radicals as cyclohexyl, cyclopentyl, etc. and alkyl substituents thereof may be used. Exemplary R^2 radicals include methyl, ethyl, propyl, t-butyl, isobutyl, n-octyl etc. In preferred

embodiments of the present invention, R and R^1 are the same and even more preferably are 2,4,4-trimethylpentyl radicals and R^2 is isopropyl or heptyl.

Illustrative compounds within the above formula for use as collectors in accordance with the present invention include:

2,4,6-triisopropyl-1,3-dioxa-5-phosphacyclohexane dithioic salt;

2,4,6-triheptyl-1,3-dioxa-5-phosphacyclohexane dithioic salt;

bis(2,4,4-trimethylpentyl)dithiophosphinate;

dipentyldithiophosphinate;

dicyclohexyldithiophosphinate;

di-n-octyldithiophosphinate;

4-methyl-1-phosphacyclohexane dithioic salt; and the like.

The dithiophosphinates may be prepared as disclosed in U.S. Patent No. 3,238,248.

The following examples are set forth for purposes of illustration only and are not to be construed as limiting the instant invention except as set forth in the appended claims. All parts and percentages are by weight unless otherwise specified. The dosage of collector is indicated as GPT, grams per ton.

The samples utilized in the following examples may be conditioned by any known procedure. For purposes of exemplification, there are set out below related procedures which may be followed depending primarily on the pH to be used and the source of the sample to be treated.

PROCEDURE A

ACID CIRCUIT PRECIOUS METALS FLOTATION SAMPLE

GOLD AND SILVER

(Samples received as damp, preground solids or high density pulps)

1) Damp, preground solids are repulped to 50% solids, by mass, with water.
2) Pulp is mechanically stirred and acid is added to adjust pH to 3.8.
3) Pulp is conditioned for 30 minutes.
4) The resultant pulp is transferred to a flotation machine (a Denver D12) and the density is adjusted to 33% solids by mass with water. (500 gram Denver cell used).
5) The flotation machine speed is set at 1300 rpm.
6) Addition of reagent:
   a) Depressant (10-100 gpt)
   b) Collector
   c) Frother (10-100 gpt)
7) Condition for 1 minute.
8) Addition of reagents.
   d) Copper sulfate modifier (40-60 gpt)
9) Condition for 0.5 minute.
10) Open the gasflow (air) and set to 8 1 pm; allow the froth to stabilize and collect the first flotation concentrate (RC1) for 1 minute.
11) Collect the second flotation concentrate (RC2) for 2 minutes.
12) Collect the third flotation concentrate (RC3) for 7 minutes. Close the gas valve.
13) Prepare the fractions (4) for analysis by accepted methods.

EXAMPLE I

Samples, are received as mine tailings. The samples are subdivided into 1 kg charges and treated as in Procedure A. The reagent collectors are 2,4,6-triisopropyl-1,3-dioxa-5-phosphacyclohexane dithioic salt (NH_4 or Na) and 2,4,6-triheptyl-1,3-dioxa-5-phosphacyclohexane dithioic salt (NH_4 or Na), designated as Collector A and Collector B, respectively. Mercaptobenzothiazole (MBT) is the auxillary collector. The results are set forth in Table I, below.

TABLE I
Part 1
Mine A

Series I Sample	Collector	GPT real	Recovery-%- Au and Ag RC1	RC2	RC3
A	MBT	30	35.8	53.9	--
B	MBT	15	42.8	56.6	--
	B	15			
C	MBT	15	39.4	58.2	
	A	15			
Series II					
D	MBT	30	18.8	42.5	--
E	MBT	15	31.5	50.7	--
	A	15			
		Part II Mine B			
F	MBT	50	33.7	47.8	54.4
G	MBT	35	28.1	42.2	48.9
	A	15			
H	MBT	25	39.3	54.0	60.6
	A	25			
I	MBT	15	51.8	61.2	65.6
	A	35			
J	A	50	35.2	45.4	50.9

The data of Table I demonstrate that the rate recoveries and overall recoveries of the synergistic combinations of the collectors of the present invention and auxiliary collector are enhanced as compared to the standard MBT, alone.

PROCEDURE B

ALKALINE CIRCUIT PRECIOUS METALS FLOTATION SAMPLE
GOLD AND SILVER

(Samples received as mill feeds of -15 mm + 0 mm size distribution)

1) A 1 kg sample of ore is charged to a laboratory ball mill with 500 ml water and lime (if required) and ground to achieve a target size of 60% passing 74 microns.
2) The resultant pulp is transferred to a flotation machine (a Denver D12) and the density is adjusted to 40% solids by mass with water. (500 gram Denver cell used).
3) The flotation machine speed is set at 900 rpm.
4) Condition pulp for 5 minutes.
5) Addition of reagents:
   a) Collector
   b) Frother (30-50 gpt)
6) The pulp is then conditioned for 4 minutes.
7) Addition of reagents:
   c) Modifier (depressant)
8) Condition for 0.5 minute.
9) Addition of reagents:
   d) Modifier - copper sulfate

10) Condition for 0.5 minute and increase machine speed to 1100 rpm.

11) Open the gasflow (air) and set to 6 lpm; allow the froth to stabilize and remove the first flotation concentrate (RC1) for 1 minute. Close the gas valve.

12) Condition for 0.5 minute.

13) Open the gasflow (air) and set to 6 lpm; allow the froth to stabilize froth to stabilize and remove the second flotation concentrate (RC2) for 3 minutes. Close the gas valve.

14) Condition for 0.5 minute.

15) Open the gasflow (air) and set to 6 lpm, allow the froth to stabilize and remove the third flotation concentrate (RC3) for 6 minutes. Close the gas valve.

16) Prepare the fractions (4) for analysis by accepted means.

EXAMPLE 2

Samples are received as mill feeds having a size distribution of about -15 mm +0 mm. The samples are subdivided into 1 kg charges and treated as in Procedure B. The collector is as specified in Table I. Sn PX is sodium n-propyl Xanthate; IPTEC is isopropyl ethyl thionocarbamate and EITC is n-ethoxycarbonyl isobutyl thionocarbamate. The results are set forth in Table II, below.

Table II

Mine A - Fresh Ore

Series I

Sample	Collector	GPT real	Recovery Au & Ag - % RC1	RC2	RC3	Sulfur - % RC1	RC2	RC3
A	SnPX	50	79.5	91.3	94.0	73.1	85.6	86.3
B	A	50	62.3	68.9	72.1	1.1	1.9	2.6
C	SnPX	35	84.5	92.3	93.7	72.0	86.5	89.0
	A	15						
D	SnPX	25	83.6	93.3	95.3	57.6	87.0	92.2
	A	25						
E	SnPX	15	80.2	90.9	93.2	49.2	77.5	80.7
	A	35						
Series II								
F	IPETC	50	73.3	86.9	91.8	18.5	38.3	54.5
G	A	50	63.4	76.5	82.3	2.0	3.4	4.3
H	IPETC	35	79.5	88.6	91.3	21.0	46.2	63.6
	A	15						
I	IPETC	25	77.5	88.2	92.0	13.0	41.4	53.0
	A	25						
J	IPETC	15	68.5	82.6	87.8	8.2	33.4	53.5
	A	35						
Series III								
K	EITC	50	78.8	87.7	90.2	38.8	64.1	70.1
L	A	50	64.6	77.4	81.5	3.0	4.7	5.8
M	EITC	35	80.1	94.1	96.1	53.6	87.1	92.6
	A	15						
N	EITC	25	77.3	82.6	85.3	9.5	12.1	13.5
	A	25						
O	EITC	15	74.5	81.6	85.1	5.4	8.4	10.5
	A	35						

The above data demonstrates the excellent gold/Silver recovery possible utilizing the dithiophosphinates of the present invention while selectively rejecting sulfides and

gold/silver locked sulfides which require further treatment prior to gold/silver recovery. At the same time, synergism with xanthates and thionocarbamates is demonstrated as well as excellent combined recovery of gold/silver.

EXAMPLE 3

These sample ores are received for testing as run of mine samples from Mine D and processed as in Procedure B. DDP is diisobutyl dithiophosphate. The results are set forth in Table III.

TABLE III

Sample	Collector	GPT real	Recovery Au & Ag - % RC1	RC2	RC3
P	SnPX	85	63.9	81.0	88.3
	DDP	25			
Q	SnPX	85	72.9	84.8	89.1
	A	25			
R	SnPX	57	72.9	84.8	89.1
	A	50			
S	SnPX	57	71.9	85.0	90.5
	B	50			

The results of Table III show the comparison between xanthate/dithiophosphate; xanthate/Collector A and xanthate/Collector B. In both cases, the replacement of the

dithiophosphate by the collectors of the present invention results in increased rates and overall recoveries of gold and silver.

PROCEDURE C

ALKALINE CIRCUIT PRECIOUS METALS FLOTATION
GOLD AND SILVER

1) Pulp is diluted to conditioning/flotation density with water to an RD of 1.34.
2) The required quantity is transferred to a Denver D12 flotation cell.
3) The flotation machine speed is set to 1550 rpm.
4) A 1 liter head sample is removed.
5) Add reagents:
   a) Collector
6) Condition 1 minute.
7) Add reagents:
   b) Frother (30-50 gpt)
8) Open air, allow froth to stabilize and remove first concentrate (RC1) for 2 minutes.
9) Remove second concentrate (RC2) for 5 minutes and close air.
10) Prepare fractions (3) for analysis by accepted means.

EXAMPLE 4

The feedstock is received as a preground pulp from the dams. The two sources are mixed (high:medium grade -3:1). The results are set forth in Table IV, below.

Table IV
Mine E
Series I

Sample	Collector	GPT real	Recovery Au & Ag - % RC1	RC2	Sulfur - % RC1	RC2
T	IPETC	1	18.6	32.3	15.1	33.0
U	A	1	18.6	31.2	2.6	5.6
		Series II				
V	IPETC	1	18.0	32.4	11.1	34.6
W	A	1	13.9	26.1	1.5	3.5
		Series III				
X	IPETC	1	18.0	32.4	11.1	34.4
Y	A	1	21.0	33.9	2.1	4.7

Table IV results demonstrate the selective gold/silver recovery ability of Collector A, clearly achieving equivalent gold/silver recoveries with extreme selectivity against pyrite (sulfur). Thus, the gold/silver is recoverable separately from that associated with pyrite, optimizing the recovery routes for gold/silver by selectively treating the fractions in the best manner.

EXAMPLE 5

Following Procedure A, dam reclamation tailings from Mine A are treated in accordance with the present invention. The results are set forth in Table V, below, In the table,

2,4,4-trimethylpentyl dithiophosphinate (Na or NH_4 salt) is designated Collector C.

Table V

Mine A

Sample	Collector	GPT real	Recovery Au & Ag - % RC1	RC2	Sulfur - % RC1	RC2
AA	MBT	30	21.8	42.2	50.8	87.3
BB	MBT	15	33.1	55.7	67.4	87.0
	C	15				

Thus, partial replacement of MBT by Collector C enhances overall rate and overall recovery of gold/silver at identical sulfur recovery, indicating that Collector C recovers gold/silver not previously recovered.

EXAMPLE 6

Procedure B is again followed. The samples tested are received as mill feeds of size distribution about 15 mm + 0 mm and are divided into 1 kg. samples by accepted means. The results are set forth in Table VI, below.

TABLE VI

MINE A

SERIES I

Sample	Collector	GPT real	Recover - Gold/Silver - % RC1	RC2	RC3
CC	SnPX	50	79.8	90.0	92.7
DD	C	50	82.0	88.3	90.7
EE	SnPX	35	81.7	91.5	94.0
	C	15			
FF	SnPX	25	85.1	93.4	95.2
	C	25			
GG	SnPX	15	83.6	90.5	92.9
	C	35			

SERIES II

FF	IPETC	50	71.9	83.0	88.1
GG	C	50	77.5	88.0	91.1
HH	IPETC	35	84.3	90.4	92.3
	C	15			
II	IPETC	25	80.1	90.1	91.6
	C	25			
JJ	IPETC	15	84.8	92.4	94.8
	C	35			

SERIES III

KK	EITC	50	69.9	77.9	84.0
LL	C	50	81.1	89.2	91.4
MM	EITC	35	81.1	86.1	88.3
	C	15			
NN	EITC	25	81.6	88.8	90.7
	C	25			
OO	EITC	15	81.6	89.6	91.1
	C	35			

SERIES IV

MINE D

PP	SnPX	57	65.1	88.4	92.8
	DDP	50			
QQ	SnPX	57	73.8	88.9	92.2
	C	50			

The synergism of the process of the present invention and improved gold/silver recovery of the compounds of the above formula are thus again shown.

EXAMPLE 7

The mechanics of Procedure C are again followed, the aim being to optimize the recovery of gold/silver by recovering, with as little cross contamination as possible, the principle precious metal fractions and sulfide gold/silver which require separate specialist treatments to recover the metals. The feedstock is that of Example 4. The results are set forth in Table VII, below.

Table VII

Mine E
Series I

Sample	Collector	GPT real	Recovery Au & Ag - % RC1	RC2	Recovery Sulfur - % RC1	RC2
RR	IPETC	1.0	18.6	32.3	15.1	33.0
SS	C	0.6	18.1	31.4	3.0	6.7
Series II						
TT	IPETC	1.0	18.0	32.4	11.1	34.6
UU	C	0.3	16.3	28.9	0.7	2.4
VV	C	0.6	17.7	29.0	1.5	2.9
WW	C	1.2	17.2	29.8	0.5	0.7

The results of Table VII clearly demonstrate the selective gold/silver recovery ability of Collector C, i.e. equivalent Au/Ag recovery with extreme selectivity against pyrite sulfur.

Example 8

An ore containing platinum group metals (PGM) and gold with pentlandite, chalcopyrite, pyrrhotite, pyrite and talc as the key constituents is treated in accordance with the present invention and the results as well as comparative showings are set forth in Table VIII, below. SIPX is sodium isopropyl xanthate.

Table VIII
Series I

Sample	Collector	GPT Real	PGM Recovery - % A	B
XX	SnPX	130	62	68
YY	SnPX	130	69	78
	C	5		

Series II

			C	D
ZZ	SIPX	102*	45	58
AAA	SIPX	102*	53	65
	C	15**		
BBB	SIPX	153**	n/a	46

* - added as 34,34,34, gpt
** - added as 5,5,5, gpt
*** - added as 51,51,51, gpt
A - ore contains 125 gpt of PGM
B - ore contains 75 gpt of PGM
C - ore contains 100 gpt of PGM
D - ore contains 50 gpt of PGM
n/a not achieved

The data of Table VIII show the improvement achieved by the synergistic combination of xanthate and dithiophosphinate compared to the xanthate alone. The results of the combination are superior to those achieved using increased xanthate additives.

EXAMPLES 9-15

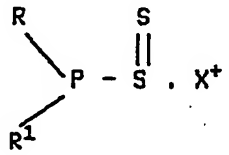
Following Example 1, various other collectors, as represented by the above formula, are utilized to treat various ores for the recovery of precious metals therefrom. The collectors are set forth in Table VIII, below. In each instance, similar results are achieved.

TABLE VII

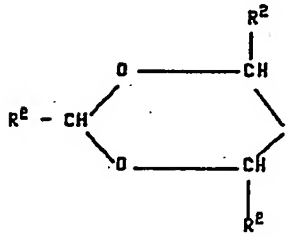
Example	Collector R	R^1	R^2	X	Primary Ore Metal	Auxiliary Collector
9	C_6H_{11}	C_6H_{11}	--	NH4	Pt/Pd	None
10	--	--	CH_3	H	Au	MBT
11	cyclo-hexyl		--	Na	Pt	DDP
12	--	--	C_2H_5	15	Ag	None
13	--	--	C_6H_{11}	NH_4	Au	IPETC
14	C_8H_{17}	C_8H_{17}	--	Na	Au	SnPX
15	C_5H_{11}	C_5H_{11}	--	Na	Au/Pt	MBT

0,778 WHAT IS CLAIMED IS:

1. In a froth flotation process for beneficiating a sulfide ore containing platinum, gold and/or silver comprising slurring liberation sized particles of said ore in an aqueous medium, conditioning said slurry with effective amounts of a frothing agent and a collector, respectively, and frothing the desired platinum, gold and/or silver containing sulfide minerals by froth flotation methods, the improvement comprising: employing as the collector, at least one dithiophosphinate compound having the formula



wherein R and R^1 are, individually, C_5-C_{12} alkyl radicals or R and R^1, together, form a cycloalkyl C_4-C_{10} or a



R^2 is a C_1-C_8 alkyl radical and X is a cation.

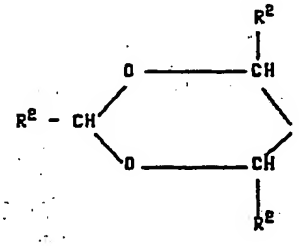
2. A process as recited in Claim 1, wherein said collector is added in an amount of from about 0.005 to about 0.5 lb/ton of ore.

3. A process as recited in Claim 1, wherein said aqueous slurry of liberation-sized ore particles has a pH value of from about 3.5 to about 11.0, inclusive.

4. A process as recited in Claim 1, wherein R and R^1 are each a C_1 - C_8 alkyl radical.

5. A process as recited in Claim 4, wherein R and R^1 are each trimethylpentyl.

6. A process as recited in Claim 1, wherein R and R^1, together, form a



7. A process according to Claim 6 wherein R^2 is isopropyl.

8. A process as recited in Claim 1, wherein in said collector is used in conjunction with a second collector.

9. A process as recited in Claim 1, wherein in said second collector is a dithionocarbamate, a dithiophosphate, a monothiophosphate, a dithiophosphonate, a mercaptobenzothiazole or a xanthate.

Patents Act 1977
Examiner's report to the Comptroller under Section 17 (The Search Report)

Application number
GB 9212173.0

Relevant Technical fields

(i) UK Cl (Edition K) B2H

(ii) Int Cl (Edition 5) B03D

Search Examiner
R E SHOEFIELD

Databases (see over)

(i) UK Patent Office

(ii) ONLINE DATABASES: WPI

Date of Search
11 SEPTEMBER 1

Documents considered relevant following a search in respect of claims 1-9

Category (see over)	Identity of document and relevant passages	Relevant t claim(s)
X	CA 1105156 (AMERICAN CYANAMID COMPANY) - see especially page 5 lines 24-27	1,8
X	US 4929344 (AMERICAN CYANAMID COMPANY) - see especially column 4, lines 56-58	1,8,!
X	US 3355017 (AMERICAN CYANAMID COMPANY) - whole document	1

Category	Identity of document and relevant passages	Relevant to claim(s)

Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family, corresponding document.

Databases: The UK Patent Office database comprises classified collections of GB, EP, WO and US patent specifications as outlined periodically in the Official Journal (Patents). The on-line databases considered for search are also listed periodically in the Official Journal (Patents).